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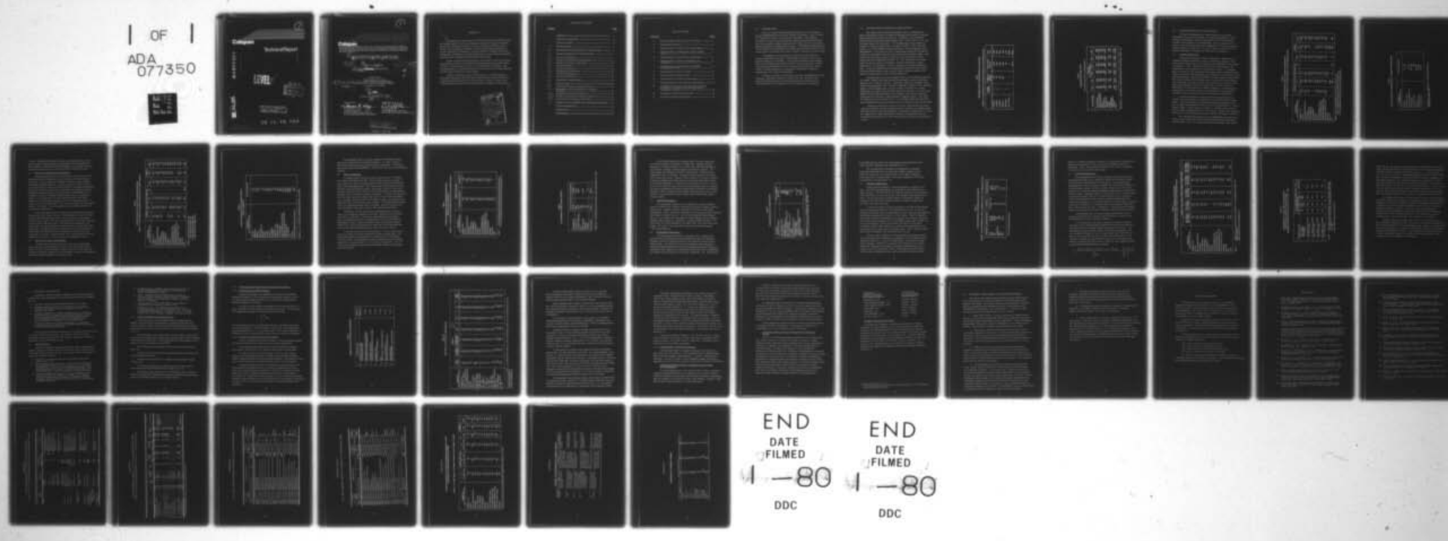

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CHARACTERIZATION STUDIES OF WASTEWATER GENERATED FROM MILITARY INSTALLATIONS.

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Prepared by

Lawrence K. Wang

Lawrence K. Wang
Project Engineer
Environmental Sciences Section
Environmental Systems Department

Approved by

Roland J. Pilié

Roland J. Pilié
Assistant Department Head
Environmental Systems Department

Calspan Corporation
Buffalo, New York 14221

408 460

ABSTRACT

The objective of this research was directed toward the identification of the characteristics of various wastewater streams generated from military bare bases. Data on the sources, volume, and nature of military wastewaters, such as laundry wastewater, kitchen and dining hall wastewaters, shower and lavatory wastewaters, human wastewater, hospital wastewater, photographic wastewaters, washrack wastewaters, and combined wastewaters, were surveyed, compiled and documented in this report.

Based on the characteristic data for field kitchen, shower and laundry wastewaters, the nature of combined wastewaters derived from these three sources at various flow proportions was mathematically calculated. The calculated data for combined wastewaters were found to be in close agreement with the meausred data for actual samples.

Synthetic wastewater prepared with tap water, laundry detergent, dishwasher detergent, ground bar soap, Bentonite clay, lubricating oil and canned dog food was found to have characteristics similar to those of the combined wastewater derived from field kitchens, laundries, and showers.

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1.0 INTRODUCTION

The U. S. Army Mobility Equipment Research and Development Center (USAMERDC) has authorized Calspan Corporation, under Contract No. DAAK02-73-C-0206, to develop test method(s), technique(s) or device(s) to be used for determining the optimum operational parameters in a carbon-polymer system designed for the treatment of various wastewaters generated in field military facilities. The program emphasizes the use of existing Army Standard water purification units (described in Ref. 1) as the major components of the carbon-polymer wastewater treatment unit.

A compilation of the physical and chemical characteristics of various wastewaters generated in field military facilities is one of four research tasks to be undertaken. This report summarizes the available data on the quantities and characteristics of laundry wastewater, kitchen and diningroom wastewaters, shower and lavatory wastewaters, human wastes, hospital wastewaters, photographic wastewaters, washrack wastewaters, and combined wastewaters.

Synthetic wastewater prepared by tap water, biodegradable laundry detergent, dishwasher detergent, military bar soap, Bentonite clay, SAE-10 lubricating oil and canned dog food has been analyzed for its characteristics, and is suggested for use in laboratory investigations.

2.0 SOURCES AND QUANTITIES OF WASTEWATERS

The major water-consuming operation units at a military bare base will generally consist of kitchens (including dining rooms), laundries, latrines (including lavatory and shower), a hospital, and an industrial unit (including washrack and photographic unit). These units, in turn, are the major sources of wastewater. The average water requirements for a typical 1,500-man military base, as listed in Table 1, were estimated by the U. S. Army Mobility Equipment Research and Development Center (USAMERDC). On the basis of water consumption totaling 56,700 gpd per 1,500 men, wastewater flow will range from 22 to 32 gpd per capita. This is due to the fact that normally only 60 to 80 per cent of water used is channelled to the wastewater flow (Ref. 2). The remainder of the water, which is spent for human consumption, material preparation, spills, evaporation, and infiltration, will not contribute to the total wastewater flow. It may be assumed that the proportionate wastewater flows arising from the aforementioned major sources would be closely related to the amount of water usages in each of these operations.

Snoeyink (Ref. 3) has also compiled data on the wastewater quantities for another military field base having the wastewater sources of kitchens, dining rooms, laundries, showers, lavatories, latrines, a hospital, wash-racks and photographic units. His data, indicated in Table 2, were estimated based on the assumption that no major overhaul maintenance or repair capabilities for military facilities are planned for the base. It is seen from Table 2 that the total wastewater of the military base for each 1000-man increment is 34,150 gpd, or approximately 34 gpd per capita. This value is in agreement with the range of 22 to 32 gpd/capita which was estimated by the USAMERDC for the wastewater flows of a military field base operation.

Additional information for the Army water requirements, the water equipment issued to the Army engineering units, and the Army adopted water and waste materiel for field operations, are indicated in Appendices I, II and III, respectively. Other information regarding the quantities of various wastewaters generated from a USAF bare base can be found from References 4 and 5.

Table 1

BARE BASE WATER REQUIREMENTS FOR 1500 MEN

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

	NUMBER OF UNITS	NUMBER OF PEOPLE PER UNIT	WATER USAGE GPD/UNIT	TOTAL GPD
KITCHEN	5	300	1,800	9,000
LATRINES	12	125	1,500	18,000
LAUNDRY	3	500	2,000	6,000
HOSPITAL	1	1,500	1,000	1,000
INDUSTRIAL	9	––	300	2,700
TIPPY (PHOTO)	1	––	––	20,000
			TOTAL	56,700

Table 2

WASTEWATER QUANTITIES*

(ALL VALUES ARE IN U.S. GALLONS PER DAY)

WASTE STREAM	BASE SIZE (NO. OF PERSONNEL)					
	1000	2000	3000	4000	5000	6000
PHOTOGRAPHIC	1600	3200	4800	6400	8000	9600
AIRCRAFT WASHRACK	3000	6000	9000	12,000	15,000	18,000
VEHICLE WASHRACK	1000	2000	3000	4000	5000	6000
HOSPITAL	500	1000	1500	2000	2500	3000
HUMAN WASTE	550	1100	1650	2200	2750	3300
LAVATORY AND SHOWER	20,000	40,000	60,000	80,000	100,000	120,000
KITCHEN	1400	2800	4200	5600	7000	8400
DINING ROOM (DISHWASHERS)	600	1200	1800	2400	3000	3600
LAUNDRY	5500	11,000	16,500	22,000	27,500	33,000
TOTAL	34,150	68,300	102,450	136,600	170,750	204,900

*SNOEYINK, V.L., "USAF MOBILITY PROGRAM WASTEWATER TREATMENT SYSTEM," 1972

3.0 CHARACTERISTICS OF WASTEWATERS

Valuable data regarding the characteristics of the kitchen wastewater, the laundry wastewater, the shower wastewater, and the combined wastewaters, which are generated from the field military facilities were supplied by the USAMERDC, and are compiled in this report. Many of the other data were originated from the Environmental Health Laboratory, Kelly Air Force Base, Texas, and the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico.

3.1 Laundry Wastewaters

Pollutants derived from laundry wastewaters consist mainly of synthetic detergents, bleaches, soaps, and soil from clothing. Some field laundry wastewaters were analyzed by the USAMERDC from August to September, 1972. Both the raw data and summarized data of the wastewater's characterization are documented in Table 3. Important data in the table are the ranges and the average values of total dissolved solids, detergents, total phosphate, total hardness, total alkalinity, 5-day biochemical oxygen demand (5-day BOD), and total organic carbon (TOC). The characteristics of the tap water used in conjunction with producing such wastewater were also analyzed during the earlier period of wastewater characterization studies in August 1972, and are reported in Appendix IV. The net amount of a specific pollutant, such as detergent, contributed by the laundry waste can be calculated by subtracting the detergent content of tap water from that of the laundry wastewater.

It is assumed that the laundry wastewaters generated from a military base are similar in composition to commercial laundry wastewaters. The characteristics of commercial laundry wastewaters have been compiled by Snoeyink et al (Ref. 3) from two texts (Refs. 6, 7), and listed in Table 4 of this report as reference. Valuable data in Table 4 are the ranges of suspended solids, total solids, volatile solids, alkalinity above pH 7.0, and oil and grease values, which do not appear in Table 3.

The 5-day BOD data analyzed by the USAMERDC was 339.0 mg/l which is close to the lower end of the BOD range (370-635 mg/l) given by References 6 and 7 for commercial laundry wastewaters (see Tables

Table 3

CHARACTERISTICS OF FIELD LAUNDRY WASTEWATERS

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

PARAMETER (mg/ℓ EXCEPT AS NOTED)	CHEMICAL ANALYSIS OF WASTEWATERS				SUMMARY		
	A	B[1]	C[2]	D[3]	MIN.	AVE.	MAX.
TURBIDITY, JTU	220.0	3,800.0	68.0	–	68.0	1,362.7	3,800.0
pH, UNIT	7.2	7.6	7.3	–	7.2	7.4	7.6
TOTAL DISSOLVED SOLIDS	410.0	290.0	800.0	–	290.0	500.0	800.0
DETERGENT	1.6	6.5	0.2	–	0.2	2.8	6.5
TOTAL PHOSPHATE	51.0	48.0	128.0	–	48.0	75.7	128.0
ORTHO PHOSPHATE	–	45.0	122.0	–	45.0	–	122.0
POLY PHOSPHATE	–	3.0	6.0	–	3.0	–	6.0
SULPHATE	13.0	175.0	55.0	–	13.0	81.0	175.0
SILICATE	60.0	150.0	72.0	–	60.0	94.0	150.0
TOTAL HARDNESS (Ca CO_3)	34.0	30.0	26.0	–	26.0	30.0	34.0
CALCIUM HARDNESS (Ca CO_3)	32.0	22.0	14.0	–	14.0	22.7	32.0
MAGNESIUM HARDNESS (Ca CO_3)	2.0	8.0	12.0	–	2.0	7.3	12.0
TOTAL ALKALINITY (Ca CO_3)	286.0	116.0	281.0	–	116.0	227.0	286.0
CHLORIDE	–	–	130.0	–	–	130.0	–
BOD, 5-DAY	–	339.0	–	–	–	339.0	–
TOC	–	258.0	14.0	28.5	14.0	100.2	258.0

NOTES: 1. FIELD LAUNDRY SAMPLE ANALYZED ON 3 AUGUST 1972;

2. POST LAUNDROMAT SAMPLE ANALYZED ON 14 AUGUST 1972;

3. POST LAUNDROMAT SAMPLE ANALYZED ON 5 SEPTEMBER 1972.

Table 4

CHARACTERISTICS OF COMMERCIAL LAUNDRY WASTEWATERS*

PARAMETER (mg/ℓ EXCEPT AS NOTED)	DATA OF ANALYSIS
pH, UNITS	9.0 - 10.3
TOTAL ALKALINITY	- 511
ALKALINITY ABOVE pH 7.0	60 - 250
TOTAL SOLIDS	800 - 2,100
VOLATILE SOLIDS	- 1,500
BOD, 5-DAY	370 - 635
SUSPENDED SOLIDS	210 - 540
OIL AND GREASE	170 - 550

*SNOEYINK, V.L., et al., "USAF MOBILITY PROGRAM WASTEWATER TREATMENT SYSTEM," 1972

3 and 4). Significant differences between the military laundry wastewater and the commercial laundry wastewaters could be the pH and total alkalinity. Both the pH and total alkalinity of the military laundry wastewaters were found to be lower than that of commercial ones.

3.2 Kitchen and Dining Room Wastewaters

Waste streams derived from the kitchen and dining hall contain dishwashing debris (detergents, soaps, greases, food and beverage left-overs, and any substances deposited on dishes), drain cleaners, household chemicals (bleaches, ammonia, polishes, waxes, solvents, ink, insect sprays), body soil and other liquid or semi-liquid substances found in the kitchen or dining hall. Raw data on the characteristics of field kitchen wastewater were received from the USAMERDC and are compiled in Table 5. Important characteristic data, as indicated in Table 5, are average pH, 6.5; total dissolved solids, 346.7 mg/l; detergent, 8.4 mg/l; total phosphate, 62.3 mg/l; total hardness, 33.7 mg/l as Ca CO_3; total alkalinity, 145.3 mg/l as $CaCO_3$; and total organic carbon, 183.3 mg/l. The characteristics of the related tap water can be found from Appendix IV.

Gouveia and Hooton (Ref. 8) analyzed the kitchen waste stream at Williams Air Force Base, Arizona. The following are some important characteristic data reported by Gouveia and Hooton: oil and grease, 578 mg/l; total solids, 3552 mg/l; suspended solids, 2500 mg/l; chemical oxygen demand, 2800 mg/l; pH, 6.0; and specific conductance, 950 micromhos/cm. Special attention should be paid to its high COD (2,800 mg/l) value. Whether the kitchen wastewater analyzed by Gouveia and Hooton (Ref. 8) contained the ground garbage and/or the dining hall wastewater is unknown. Additional data on the characteristics of kitchen wastewater from the Air Force bare base are indicated in Table 6.

3.3 Shower and Lavatory Wastewaters

Wastewaters from the shower rooms will contain detergents, soaps, greases, drain cleansers, bleaches, solvents, insect sprays, body soil, urine, and occasionally vomitus and feces. When sinks are installed, additional materials such as toothpaste, saliva, and nasopharyngeal mucus will be included in the waste stream.

Table 5

CHARACTERISTICS OF FIELD KITCHEN WASTEWATERS

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

PARAMETER (mg/ℓ EXCEPT AS NOTED)	CHEMICAL ANALYSIS OF WASTEWATERS				SUMMARY		
	A[1]	B[2]	C[3]	D[4]	MIN.	AVE.	MAX.
TURBIDITY, JTU	46.0	440.0	77.0	–	46.0	187.7	440.0
pH, UNIT	6.3	6.3	6.8	–	6.3	6.5	6.8
TOTAL DISSOLVED SOLIDS	295.0	430.0	315.0	–	295.0	346.7	430.0
DETERGENT	8.2	8.4	8.6	–	8.2	8.4	8.6
TOTAL PHOSPHATE	81.0	52.0	54.0	–	52.0	62.3	81.0
ORTHO PHOSPHATE	–	36.0	42.0	–	36.0	39.0	42.0
POLY PHOSPHATE	–	16.0	12.0	–	12.0	14.0	16.0
SULPHATE	7.0	–	36.0	–	7.0	21.5	36.0
SILICATE	170.0	170.0	–	–	170.0	170.0	170.0
TOTAL HARDNESS (Ca CO_3)	51.0	28.0	22.0	–	22.0	33.7	51.0
CALCIUM HARDNESS (Ca CO_3)	–	26.0	11.0	–	11.0	–	26.0
MAGNESIUM HARDNESS (Ca CO_3)	–	2.0	11.0	–	2.0	–	11.0
TOTAL ALKALINITY (Ca CO_3)	170.0	120.0	146.0	–	120.0	145.3	170.0
CHLORIDE	–	35.0	33.0	–	33.0	34.0	35.0
BOD, 5-DAY	–	–	–	–	–	–	–
TOC	102.0	214.0	268.0	149.0	102.0	183.3	268.0

NOTES: 1. ANALYZED ON 16 AUGUST 1972;
2. ANALYZED ON 4 AUGUST 1972;
3. ANALYZED ON 10 AUGUST 1972;
4. ANALYZED ON 5 SEPTEMBER 1972.

Table 6

CHARACTERISTICS OF KITCHEN WASTEWATER FROM A HOSPITAL*

PARAMETER (mg/ℓ EXCEPT AS NOTED)	DATA OF ANALYSIS
CALCIUM	41.0
MAGNESIUM	8.0
SODIUM	171.0
POTASSIUM	10.0
IRON (DISSOLVED)	1.3
AMMONIA	4.0
SILICATE	50.0
CHLORIDE	170.0
SULFATE	66.0
BICARBONATE	181.0
CARBONATE	0.0
PHOSPHATE, TOTAL	28.0
PHOSPHATE, ORTHO	25.0
OIL AND GREASE	878.0
DISSOLVED SOLIDS (CALCULATED)	730.0
DISSOLVED SOLIDS (EVAPORATION)	1,071.0
SUSPENDED SOLIDS	2,498.0
TOTAL SOLIDS	3,552.0
COD	2,800.0
pH, UNITS	6.0
SPECIFIC CONDUCTANCE (micromhos/cm)	950.0

*GOUVEIA, A., et al., "CHEMICAL ENGINEERING PROGRESS," 64, 90, 1968.

No quantitative data for shower wastewater and lavatory wastewater were reported in the published literature. The data in Table 7 indicate the characteristics of the field shower wastewater. These data were received from the USAMERDC, which is the sole source of information available.

3.4 Human Wastewater

A military latrine produces mainly human excreta. According to the Ehlers and Steel's text (Ref. 9), the human excreta are small in daily volume per capita, averaging about 83,000 mg of feces and 970,000 mg of urine (including water). The human waste includes large amounts of water; some putrescible organics, amounting to about 2.5 per cent of the urine and 20 per cent of the feces; and small amounts of phosphorous, nitrogen, sulfur, and other inorganic compounds. The text also states that when the human excreta is diluted with water to form human wastewater (i.e., sewage), at the rate of 30 to 100 gpd per capita, an average human wastewater may have about 800 mg/l of solids, so composed that 300 mg/l will be in suspension and 500 mg/l in solution. About 50 percent of the total wastewater solids will be organic and therefore putrescible.

Webb (Ref. 17) has reported the contaminants from urine and feces on the weight per capita per day basis. His data are summarized in Table 8 for reference. It should be noted that Ehlers and Steels data, averaging about 83,000 mg/capita/day of feces and 970,000 mg/capita/day of urine, include the weight of water in the human wastes. Webb's data, 29,010 mg/capita/day of feces and 77,840 mg/capita/day of urine, are total solids (see Table 8) which exclude the water.

Two other sources of information (Refs. 4, 10) on human wastewater are limited to only the wastewater's solids concentration. The Garrett Airesearch Corporation (Ref. 4) and the Air Force Weapons Laboratory (Ref. 10) reported the solids concentration of human wastewater to be 15 percent, and 5.6 to 6.7 percent, respectively. It is not clear from the papers whether the human wastes analyzed were diluted with toilet waters.

Table 7

CHARACTERISTICS OF FIELD SHOWER WASTEWATER
AND RELATED TAP WATER

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

PARAMETER (mg/ℓ EXCEPT AS NOTED)	CHEMICAL ANALYSIS	
	SHOWER WASTEWATER[1]	TAP WATER[1]
TURBIDITY, JTU	59.0	0.34
pH, UNIT	6.8	7.9
TOTAL DISSOLVED SOLIDS	175.0	135.0
DETERGENT	1.75	0.04
TOTAL PHOSPHATE	35.0	20.0
ORTHO PHOSPHATE	28.0	12.0
POLY PHOSPHATE	7.0	8.0
SULPHATE	22.0	22.0
SILICATE	55.0	36.0
TOTAL HARDNESS (Ca CO_3)	18.0	12.0
CALCIUM HARDNESS (Ca CO_3)	16.0	12.0
MAGNESIUM HARDNESS (Ca CO_3)	2.0	0.0
TOTAL ALKALINITY	136.0	108.0
CHLORIDE	10.0	10.0
BOD, 5-DAY	51.0	–
TOC[2]	15.0	–

NOTES: 1. ALL PARAMETERS EXCEPT TOC WERE ANALYZED ON 2 AUGUST 1972;
2. TOC OF THE SHOWER WASTEWATER WAS ANALYZED ON 28 AUGUST 1972.

Table 8
CONTAMINANTS FROM HUMAN WASTES*

CONTAMINANTS	DATA OF ANALYSIS, mg/CAPITA/DAY	
	URINE	FAECES
ELECTROLYTES	29,650	3,030
NITROGEN COMPOUNDS	44,630	15,070
ACIDS	2,380	--
MISC. ORGANICS	1,670	10,900
HORMONES	280	--
VITAMINS	230	10
TOTAL SOLIDS	77,840	29,010

* WEBB, P.M.D., "BIOASTRONAUTICS DATA BOOK," NASA, WASHINGTON, D.C.; 1967.

More detailed data on the characteristics of human wastewater have been reported by Hernandez et al (Ref. 20). Samples of human wastes were collected aboard a U. S. Navy ship, USS FULTON (AS-11), for physical, biological, bacteriological and chemical analysis. The ship's piping was modifeid so that the representative combined human wastewater could be collected. Twenty-five waste samples were taken over a three-day period. Results of these analyses are shown in Table 9. It should be pointed out that the chloride content and total solids content of the human wastewater on shipboard were analyzed to be high. This is due to the fact that sea water was used as the flushing water on shipboard. The human wastewater (including flushing water) generated from military latrines on land is believed to have similar characteristics as that listed in Table 9 except that the chloride content and the total solids content should be lower.

3.5 Hospital Wastewater

The wastewater streams from a hospital will contain pollutants similar to those from a military unit having the kitchen, laundry, latrines and showers. Besides, hospital wastewaters will also include blood, disinfectants, drugs, laboratory chemicals, and X-ray processing chemicals. According to a report from U. S. Army Environmental Hygiene Agency (Ref. 11), the average concentrations of major pollutants in the combined hospital waste stream are: detergent, 75 mg/l as ABS; chromium, 1.05 mg/l; lead, 0.32 mg/l; phosphate, 166 mg/l; COD, 870 mg/l; and oil and grease, 43.4 mg/l. The conductivity of the waste stream averages 1,530 micromhos/cm.

3.6 Photographic Wastewater

The photographic wastewater discharged from a military base includes about 10 percent processing liquids and 90 percent washwater. Generally, the EA-4 chemical process is the common process used in a military base. The COD values of the concentrated processing liquid waste (excluding washwater) and the total combined wastewater (including washwater) were analyzed to be 78,500 mg/l and 8,108 mg/l, respectively, by Lefebvre et al at Kelly Air Force Base, Texas (Ref. 12). The COD-to-

Table 9

CHARACTERISTICS OF HUMAN WASTE*

PARAMETER (mg/ℓ EXCEPT AS NOTED)	DATA OF CHEMICAL ANALYSIS
FLOW, gpd/CAPITA (AVE)	20.0
BOD, 5-DAY (AVE.)	102.0
SUSPENDED SOLIDS (AVE)	236.0
VOLATILE & ORGANIC SOLIDS (AVE)	5826.0
TOTAL SOLIDS (AVE)	33000.0
SETTLEABLE SOLIDS, ml/l (AVE)	5.4
pH, RANGE	7.1 - 8.2
DISSOLVED OXYGEN (AVE)	5.4
COLIFORM, MPN/100 ml	
GEOMETRIC MEAN	4.8×10^5
GEOMETRIC STANDARD DEVIATION	12.0
TEMPERATURE °C (RANGE)	16 - 19
CHLORIDE	17500.0

*HERNANDEZ, J.W., ET AL, "TREATMENT OF SHIPBOARD WASTES," PROC. OF 21TH PURDUE IND. WASTE CONF., MAY 1966

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5-day BOD ratio for either the concentrated processing liquid or the total combined wastewater was estimated to be 4.4

The concentrated fractionation of photographic wastewater (excluding washwater) has very high heavy metals content; such as: lead, 0.57 mg/l; zinc, 0.30 mg/l; silver, 214.0 mg/l; chromium, 2.66 mg/l; iron, 15 mg/l; copper, 0.05 mg/l; manganese, 0.05 mg/l; and cadmium, 0.09 mg/l (Ref. 12).

3.7 Washrack Wastewaters

Simple washing operation is always expected at a military bare base. The washrack wastewaters can generally be subdivided into two basic fractions. The first fraction is composed mainly of those materials in the dirt films, such as soil, grease, oil, oxidized metal particles and salts. The second fraction consists mainly of detergents, soaps, and solvents which are used to clean the surfaces of vehicle, watercraft, aircraft or any other equipment.

A series of technical reports prepared by the USAF Environmental Health Laboratory at Kelly Air Force Base (Refs. 13, 14, 15, 16) have presented some data on the characteristics of vehicle and aircraft washrack wastewaters generated from some Air Force bases. Table 10 indicates some data of washrack wastewater from George, Dover and Mc Chord Air Force bases which originally were summarized by Snoeyink et al (Ref. 3). It was reported (Ref. 3) that the analyses were based on many daily composite samples being collected in a manner which excluded free oil and grease and, to some extent, settleable solids. Some washrack wastewater flows investigated even contained storm run off.

There is wide variability in characteristics and quantity of washrack wastewater from installation to installation due to the differences in operation, maintenance, type of cleaning agents, and method of wastewater transport. However, the general characteristics of the vehicle, watercraft, aircraft, and equipment washrack wastewaters are very similar to those of each other. Table 10 indicates that the COD, BOD, oil and grease, detergent, phenol, and heavy metals content would be

Table 10

CHARACTERISTICS OF WASHRACK WASTEWATER

(SOURCE: USAF ENVIRONMENTAL HEALTH LABORATORY, KELLY AIR FORCE BASE, TEXAS)

PARAMETER	CONCENTRATION*	PARAMETER	CONCENTRATION
COD	420-916	PHENOL TOTAL	.02-6.7
BOD	135-300	Cr	.08-1.9
TDS	500-580	Cu	.04-.14
SS	27-60	Cd	.02-.03
OIL/GREASE	4-50	Ag	- .09
MBAS	3-160	Fe	.l-.7
NO_3	1-7	Pb	.l-.2
PO_4	18-105	Zn	.1-.8
		pH	7-8

*ALL VALUES IN mg/1 EXCEPT pH.

high for a combined washrack wastewater. Oil and grease usually form stabilized emulsions due to the action of the emulsifier found in the detergents. These oil and grease emulsions were found to be difficult to remove from the washrack wastewater.

3.8 Combined Wastewaters

The characteristics of various combined waste streams will be important information for an operator to decide the chemicals' dosage when combined waste treatment is considered. Two possible waste combinations for the Air Force bare bases have been researched (Ref. 3). If only hospital, shower, lavatory, kitchen, dining room, and laundry wastes are combined (excluding photographic and washrack wastewaters), the total solids, suspended solids, and 5-day BOD of such combined waste will be approximately 750 mg/l, 510 mg/l and 434 mg/l, respectively. If all the aforementioned waste streams including photographic and washrack wastewaters, are combined together, the total solids, suspended solids and 5-day BOD of the combined waste will be approximately 800 mg/l, 454 mg/l and 410 mg/l, respectively. These data were estimated based on the proportions of major wastewater flows indicated in Table 2.

Characteristic data on some combined wastewaters from the sources of field showers, laundries and kitchens were received from the USAMERDC, and are reported in Table 11.

It is of interest to note that the nature of a specific combined wastewater can be mathematically estimated when both the quality and the percent flow of each participating waste stream are known. The characteristic data of laundry, kitchen and shower wastewaters have been compiled in Tables 3, 5 and 7, respectively; their TOC data are listed in the top portion of Table 12 as the control information. The minimum, average and maximum TOC data for four combined wastewaters, as listed in the first column of Table 12, were estimated based on the following material balance equation:

$$C_c = \frac{Q_1 C_1 + Q_2 C_2 + Q_3 C_3 + \cdots\cdots + Q_n C_n}{\sum_{i=1}^{n} Q_i} = \frac{\sum_{i=1}^{n} (Q_i C_i)}{\sum_{i=1}^{n} Q_i}$$

Table 11

CHARACTERISTICS OF FIELD COMBINED WASTEWATERS

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

PARAMETER (mg/ℓ EXCEPT AS NOTED)	CHEMICAL ANALYSIS OF VARIOUS COMBINED WASTEWATERS[1]				
	A 30% SHOWER 40% LAUNDRY 30% KITCHEN	B 50% SHOWER 40% LAUNDRY 10% KITCHEN	C 70% SHOWER 15% LAUNDRY 15% KITCHEN	D 80% SHOWER 10% LAUNDRY 10% KITCHEN	E 50% SHOWER 40% LAUNDRY 10% KITCHEN
TURBIDITY, JTU	46.0	220.0	42.0	38.0	70.0
pH, UNIT	6.7	6.7	6.8	6.7	6.9
TOTAL DISSOLVED SOLIDS	430.0	190.0	250.0	315.0	450.0
DETERGENT	12.3	3.5	8.1	8.3	6.2
TOTAL PHOSPHATE	130.0	48.0	67.0	72.0	127.0
ORTHO PHOSPHATE	108.0	35.0	58.0	65.0	88.0
POLY PHOSPHATE	22.0	13.0	9.0	7.0	39.0
SULPHATE	35.0	–	5.0	46.0	–
SILICATE	170.0	–	160.0	150.0	–
TOTAL HARDNESS ($Ca\ CO_3$)	28.0	17.0	21.0	13.0	20.0
CALCIUM HARDNESS ($Ca\ CO_3$)	16.0	13.0	10.0	8.0	14.0
MAGNESIUM HARDNESS ($Ca\ CO_3$)	12.0	4.0	11.0	5.0	6.0
TOTAL ALKALINITY ($Ca\ CO_3$)	172.0	135.0	153.0	171.0	225.0
CHLORIDE	69.0	11.3	29.0	44.0	15.3
BOD, 5-DAY	–	100.0	–	–	–
TOC	115.0	146.0	59.0	38.0	–
TOC[2]	96.0	54.5	44.0	32.0	112.5

NOTES: 1. SAMPLES A, B, C, D AND E ANALYZED ON 10th, 8th, 11th, 15th AND 9th OF AUGUST, 1972. EXCEPT AS NOTED.

2. SAMPLES ANALYZED ON 5 SEPTEMBER 1972.

Table 12

COMPARISON OF ANALYZED TOC DATA WITH CALCULATED TOC DATA FOR DIFFERENT COMBINED WASTEWATERS COLLECTED IN THE FIELD

WASTEWATER FLOW	TOTAL ORGANIC CARBON (TOC), mg/ℓ			
	CALCULATED[1]			ANALYZED[2]
	MIN	AVE	MAX	
100% KITCHEN	102	183.3	268.0	--
100% LAUNDRY	14	100.2	258.0	--
100% SHOWER	--	15.0	--	--
A. 30% SHOWER, 40% LAUNDRY AND 30% KITCHEN	40.7	99.6	188.0	115.0
B. 50% SHOWER, 40% LAUNDRY AND 10% KITCHEN	23.3	65.8	137.3	146.0
C. 70% SHOWER, 15% LAUNDRY AND 15% KITCHEN	27.9	52.9	89.4	59.0
D. 80% SHOWER, 10% LAUNDRY AND 10% KITCHEN	23.6	40.4	64.6	38.0

NOTES:
1. DATA WERE CALCULATED BASED ON THE PER CENT FLOWS AND THE QUALITIES OF THREE WASTE STREAMS COMPILED IN TABLES 3, 5, AND 7.
2. DATA WERE SELECTED FROM TABLE 11.

where Q_1, Q_2, Q_3 and Q_n are the flow (or percent flow) of shower wastewater, laundry wastewater, kitchen wastewater, and any other wastewater, respectively; ΣQ is the summation of Q_1, Q_2, Q_3, ..., and Q_n; and C_1, C_2, C_3, C_n, and C_c are the concentration parameters (such as TOC, BOD, etc.) of shower wastewater, laundry wastewater, kitchen wastewater, any individual wastewater, and combined wastewater, respectively. Actual analyzed TOC data of four different combined wastewaters, as indicated in the second column of Table 12, are selected from Table 11. It is seen from Table 12 that the analyzed TOC data of combined wastewaters A, C and D are very close to their calculated average TOC values, while the analyzed TOC of combined wastewater B is close to its calculated maximum TOC.

It is apparent that data on the nature and the flow of each individual wastewater stream are necessary for estimating the nature of the combined wastewater. Much data regarding wastewater contaminant parameters at a military bare base are already available in this report and from other published materials. However, additional effort is still required to establish reliable information on the percent flow of every participating waste stream in the combined wastewater to be considered at various operation times, such as morning, noon, afternoon, and evening.

Another alternative is using flow meters to measure the flow of each individual wastewater stream. Knowing the flow (measured data) and nature (surveyed data) of every participating waste stream, the operator can then calculate the nature of combined wastewater, and decide the chemical dosages for wastewater treatment. The feasibility of measuring the flows of major wastewater streams in a military field remains unknown until an extensive field investigation is conducted.

4.0 SYNTHETIC WASTEWATER

Preparing a suitable synthetic wastewater for the experimentation would provide many advantages over using the actual field waste samples, such as:

- The time-consuming field sampling effort can be avoided;
- Synthetic wastewater of known concentration can be used to determine the effectiveness of an analytical technique, or an analytical instrument;
- Synthetic wastewater of constant characteristic or strength can be prepared for the laboratory optimization studies; so that the optimum operational (both chemical and physical) parameters of a wastewater treatment system can be established for a specific strength of wastewater being considered; and
- Varying the strength of synthetic wastewater in optimization studies would lead to establish the chemical dosage requirements at various influent pollution loads.

The particular synthetic wastewater was formulated in this research in a manner that its characteristic was similar to that of combined wastewater derived from military field kitchens, showers and laundries, and similar to that of domestic sewage.

4.1 Materials Used

Synthetic wastewater was prepared with tap water, biodegradable laundry detergent, dishwash detergent, ground bar soap, Bentonite clay, lubricating oil, and canned dog food. The sources of these materials are described in detail as follows:

- Tap water -- Laboratory tap water at Calspan Corporation, Buffalo, New York;
- Biodegradable laundry detergent -- Cold Power manufactured by Colgate-Palmolive Co., New York, New York. It contains sodium sulfate, sodium silicate, alkylbenzene sulfonate, saop, ethoxylated alcohol, moisture, carboxymethylcellulose, cold water brighteners, aluminum silicates, colorant and perfume;
- Automatic dishwasher detergent -- Cascade Detergent manufactured by Procter & Gamble, Cincinnati, Ohio. Cascade contains complex sodium phosphates, chlorinated trisodium phosphate, nonionic surfactant, sodium silicate, sodium sulfate, colorant and perfume;

- Ground bar soap -- Military soap received from the U.S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia;
- Clay -- Powdered Volclay Bentonite SPV supplied by American Colloid Company, Skokie, Illinois. It contains silica, aluminum, iron, magnesium, sodium, potassiun, calcium, and others;
- Lubricating oil -- Heavy Duty (HD) oil, grade SAE-10, supplied by Penn Corporation, Butler, Pa.;
- Canned dog food -- Blue Ribbon Recipe (balanced and complete nutrition), packed by Rival Pet Foods, A Division of Associated Products, Inc., Bridgeview, Ill. It contains protein, fat, fiber, moisture, vitamins, minerals, and ash.

4.2 Analytical Methods and Apparatus Used

Dissolved oxygen, pH, immediate dissolved oxygen demand (IDOD), chemical oxygen demand (COD), suspended solids (SS), total solids, dissolved solids, 5-day biochemical oxygen demand (5-day BOD), total phosphate, and chloride were analyzed according to Standard Methods (Ref. 21).

Total alkalinity, total carbon (TC), and total organic carbon (TOC) were analyzed following the methods and procedures given by Environmental Protection Agency (Ref. 22). A Beckman Model 915 Total Organic Carbon Analyzer was used to analyze TC and TOC.

Dissolved protein determination was made by the Folin method (Ref. 23).

Oil and grease was determined following Standard Method (Ref. 21) with chloroform as solvent.

Resistivity was measured by a Calspan developed Spill Tracing Kit (Ref. 24).

Turbidity, total hardness, sulfate, and silicate were analyzed with a Delta Scientific Model 260 Water Analyzer (Ref. 25).

All samples being analyzed for their dissolved protein, dissolved solids, dissolved COD, dissolved total carbon, and dissolved total organic carbon were filtrates through 0.45 μ millipore filters.

4.3 Formulation and Characteristic of Synthetic Wastewater

4.3.a. Preparation of Synthetic Samples

Synthetic wastewater was prepared according to the formulation indicated in Table 13. Each ingredient was assigned a notation, such as F_1 representing laboratory tap water, F_2 representing biodegradable laundry detergent, and so forth.

In order to have thorough understanding on the characteristics of seven materials used for synthetic wastewater preparation, seven samples were prepared according to the following general formula,

$$\sum_{i=1}^{i=N} (F_i)$$

The first sample (N = 1), as indicated in Table 14, was simply tap water; the second sample (N = 2) was the mixture of tap water and biodegradable laundry detergent (i.e., $F_1 + F_2$); and so forth. The seventh sample (N = 7) containing all seven materials was the final product, synthetic wastewater.

4.3.b. Results of Chemical and Physical Analyses

Table 14 indicates the results of analyses. Its first column presents the characteristic data of tap water used for samples preparation.

It was observed that total solids, suspended solids and turbidity all increased when any one of six materials was added to the tap water.

pH values of seven samples indicated in Table 14 were closely related to their total alkalinity data. Adding laundry detergent and dish-washer detergent increased both pH and total alkalinity. The addition of soap, clay, oil and dog food had no significant effect on pH or total alkalinity.

Certain substances present in the detergents and soap reacted with hardness-causing substances (such as calcium or magnesium) in the tap water, and formed insoluble precipitates. Therefore, a reduction in total hardness of water by adding detergents and soap to water was observed (see Table 14). Resistivity of water samples, in turn, reduced when soluble hardness-causing substances became insoluble due to the addition of detergents and soap. Clay, oil and dog food had no effect on both total hardness and resistivity.

Table 13

FORMULATION OF SYNTHETIC WASTEWATER

	MATERIALS USED	QUANTITY
F_1	LABORATORY TAP WATER: (CALSPAN CORPORATION)	1000.0 GAL.
F_2	BIODEGRADABLE LAUNDRY DETERGENT: COLD POWER (COLGATE-PALMOLIVE CO.)	2.0 LB.
F_3	DISHWASHER DETERGENT: CASCADE DETERGENT (PROCTER & GAMBLE)	2.0 LB.
F_4	GROUND BAR SOAP: MILITARY SOAP (USAMERDC)	0.3 LB.
F_5	CLAY: BENTONITE SPV (AMERICAN COLLOID CO.)	0.4 LB.
F_6	SAE-10 LUBRICATING OIL: HEAVY DUTY (HD) OIL (PENN. CORP.)	0.1 LB.
F_7	CANNED DOG FOOD: BLUE RIBBON RECIPE (RIVAL PET FOODS)	3.7 LB.

Table 14
ANALYSIS OF SYNTHETIC WASTEWATER

PARAMETER (mg/ℓ EXCEPT AT NOTED)	SAMPLES*, $\sum_{i=1}^{i=N} F_i$						
	TAP WATER	+ LAUNDRY DETERGENT	+ DISHWASHER DETERGENT	+ SOAP	+ CLAY	+ OIL	+ DOG FOOD
	N = 1	N = 2	N = 3	N = 4	N = 5	N=6	N = 7**
TURBIDITY, JTU	~0	10	12	20	55	60	110
RESISTIVITY, OHM-CM	975	600	450	400	400	400	400
TOTAL ALKALINITY($CaCO_3$)	114	142	164	164	158	164	166
TOTAL HARDNESS($CaCO_3$)	127	123	104	98	97	98	96
CHLORIDE	27	31	36	34	34	32	34
SULFATE	34	120	193	185	193	180	200
SILICATE (SILICA)	1	22	26	26	24	26	47
TOTAL SOLIDS	206	428	647	674	718	728	876
DISSOLVED SOLIDS	204	326	494	472	466	428	478
SUSPENDED SOLIDS	2	102	153	202	252	300	398
DISSOLVED PROTEIN	<15	< 15	< 15	<15	<15	<15	30
COD, TOTAL	16	92	112	184	188	188	236
COD, DISSOLVED	12	80	88	116	109	124	124
TC, TOTAL	23	63	68	95	92	97	136
TC, DISSOLVED	25	50	57	64	61	53	58
TOC, TOTAL	1	41	46	73	70	75	114
TOC, DISSOLVED	3	28	35	42	39	31	36
5-DAY BOD, TOTAL	0.9	78	79	102	144	120	162
DISSOLVED OXYGEN (25°C)	9.5	8.5	8.3	8.3	8.2	8.2	8.0
IDOD (25°C)	0.0	1.0	1.2	1.2	1.3	1.3	1.5
TOTAL PHOSPHATE	0.03	0.07	28.0	27.6	29.2	29.2	30.0
OIL AND GREASE	< 3.0	17.4	20.8	28.0	24.0	26.0	47.4
pH, UNIT	7.3	9.3	9.5	9.5	9.5	9.4	9.4

*F_1, F_2, F_3, F_4, F_5, F_6 AND F_7, AS INDICATED IN TABLE 13, ARE THE MATERIALS USED FOR THE PREPARATION OF THE SYNTHETIC WASTEWATER

**SYNTHETIC WASTEWATER

From the silicate data reported in Table 14, it is seen that laundry detergent, dishwasher detergent and dog food contributed silicate content to the synthetic wastewater. Soap, clay and oil did not contribute any silicate content to the synthetic sample.

Total phosphate data in Table 14 demonstrate the following facts: (1) Cold Power laundry detergent, indeed, is a low-phosphate detergent; (2) Cascade dishwasher detergent is the major phosphate contributor to synthetic wastewater; and (3) soap, clay, oil and dog food contain low or no phosphate.

Of six kinds of materials added to the tap water for synthetic wastewater preparation, only laundry and dishwasher detergents were found to increase sulfate content significantly. These two materials also produced an insignificant increase in chloride.

Dissolved protein of synthetic samples was analyzed by Folin Method (Ref. 23). The lowest detecting limit was found to be 15 mg/l as gelatin. Therefore, the dissolved protein content of six control samples indicated in Table 14 (N = 1 to 6) is not meaningful. Dissolved protein content of synthetic wastewater (N = 7), however, was analyzed to be 30 mg/l. It is conceivable that most of protein present in dog food would be insoluble matter.

Oil and grease of samples was analyzed following the Standard Method (Ref. 21) with chloroform as solvent. It is understandable, from Section 4.1, that the laundry and dishwasher detergents used for sample preparation did not contain oil and grease in noticeable amounts. However, when laundry detergent, dishwasher detergent, and soap were added one by one to the water, the oil and grease showed up significantly (see Table 14). This can be explained by the fact that most of surface active substances present in the detergents and soap are chloroform extractable. The oil and grease data for Samples N = 2, 3 and 4 should be interpreted as chloroform extractable substances instead of oil and grease.

Oil and grease, total organic carbon, total carbon, dissolved COD, and dissolved solids of Sample N = 5 all decreased as Bentonite clay was added to the solution containing detergents and soap. It is conceivable that clay acted as an adsorbent as it presented in the synthetic sample.

The added lubricating oil (Sample N = 6), small amount but in emulsified form, was observed to increase turbidity, total solids, total carbon, total organic carbon, and oil and grease to a limited extent. It should be noted that dissolved solids, dissolved total carbon, dissolved total organic carbon, and 5-day BOD of Sample N = 6 were all lower than that of Sample N = 5. It has been mentioned earlier in Section 4.2, all samples being analyzed for their dissolved solids, dissolved total carbon, dissolved total organic carbon were filtrates through 0.45 μ Millipore filter papers. Oil might coagulate or agglomerate with certain dissolved or colloidal solids in the sample. Both oil and agglomerated substances could be lost during the Millipore filtration procedure. In turn, lower dissolved solids, dissolved total carbon, and dissolved total organic carbon were observed. The author, however, gives no explanation of why 5-day BOD of Sample N = 6 was lower than that of Sample N = 5.

Dog food was added to Sample N = 7, and was found to be a significant contributor of turbidity, silicate, total solids, suspended solids, dissolved protein, total COD, total TC, total TOC, 5-day BOD, and oil and grease, to the synthetic wastewater.

4.3.c. Characteristic of Synthetic Wastewater

Characteristic data for synthetic wastewater are listed in the last column (N = 6) of Table 14. Characteristic data of combined wastewater from field military installations (i.e., showers, laundries and kitchens), as shown in Table 11, and of domestic sewage, as shown in Appendices V and VI will be compared with the data of synthetic wastewater.

Comparison Between Synthetic Wastewater and Combined Field Wastewater

It is encouraging to see, from data in Tables 11 and 14, that the prepared synthetic wastewater has composition very similar to that of combined wastewater derived from field showers, laundries, and kitchens. Data for turbidity, total dissolved solids, total alkalnity, chloride, 5-day BOD and total organic carbon are in good agreement.

Synthetic wastewater has higher total hardness than that of combined field wastewater because high hardness tap water was used for preparing the synthetic sample (see Table 14); while low hardness tap water was used in the military field program during the period when the field wastewater samples from kitchens, showers and laundries were taken (See Appendix IV).

The total phosphate concentration of combined field wastewater, as shown in Table 11, ranged from 48 to 127 mg/l, probably due to the use of high-phosphate laundry detergent. With stricter legislation forcing limitations on the use of high-phosphate laundry detergent, non-phosphate Cascade detergent was selected for preparing synthetic wastewater. Although the total phosphate level of synthetic wastewater was as low as 30 mg/l, it will be closer to levels expected for future field wastewater.

A large difference exists between the sulfate and silicate contents of synthetic and actual wastewaters. This difference might also be contributable to the use of different types of detergents.

Comparison Between Synthetic Wastewater and Domestic Sewage

Much of the combined wastewater generated from a military field base would be similar to, although not exactly the same as, typical domestic sewage containing waste constituents from houses, apartments, restaurants, hospitals, and institutions. Physical characteristics of domestic sewage, as indicated in Appenix V, were qualitatively described by McGauhey (Ref. 26). Quantative characteristics of domestic sewage were found from Babbitt and Baumann's text (Ref. 27) and are listed in Appendix VI for the purpose of comparison. Critical characteristic parameters of laboratory-prepared synthetic wastewater are total solids, total suspended solids, total dissolved solids, 5-day BOD, chlorides, total alkalnity and oil and grease, which all fall in the range of domestic sewage composition. According to Babbitt and Baumann's classification (Ref. 27), the synthetic wastewater is approximately equivalent to a domestic sewage of medium strength based on the following facts:

Constituent of Synthetic Wastewater (all values in mg/l)	Classification of Sewage Strength (see Appendix VI)
Total Solids = 676	Medium - Strong
Total Suspended Solids = 398	Medium - Strong
Total Dissolved Solids = 478	Medium - Strong
5-day BOD = 162	Weak - Medium
Chlorides = 34	Weak - Medium
Total Alkalinity = 166	Medium - Strong
Oil and Grease = 47	Strong

Synthetic Wastewater Alternative

If photographic wastewater, washrack wastewater and hospital wastewater are also included in the combined wastewater stream for treatment, the pollutant parameters that characterize the combined wastewater will include not only general parameters for typical domestic sewage such as BOD, solids, oil and grease, etc., but also additional parameters which quantify certain constituents present in the bare base wastewater such as toxic heavy metals, refractory organics, etc.* In such a case, additional toxic heavy metals and refractory organics should also be added to the synthetic wastewater formulation indicated in Table 13.

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* These materials are not included in the wastewaters to be investigated under the present contract.

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The task of this research was directed toward the identification of the characteristics of various wastewater streams generated from military bare bases. The data and information on wastewater characterization was gathered from available literature with assistance of the USAMERDC Project Officer, Mr. Robert Ross. A concise summary, conclusions and recommendations are given as follows:

1. Data on the sources, volume, and nature of military wastewaters, such as laundry wastewater, kitchen and dining hall wastewaters, shower and lavatory wastewaters, human wastewater, hospital wastewater, photographic wastewaters, washrack wastewaters, and combined wastewaters, were surveyed, compiled, and documented in this report.

2. Based on the characteristic data for field kitchen, shower and laundry wastewaters, the nature of combined wastewaters derived from these three sources at various flow proportions was mathematically calculated. The calculated characteristic data for combined wastewaters were found to be in close agreement with the measured data for actual samples.

3. Data on the nature and the flow of each individual waste stream are necessary for estimating the nature of the combined wastewater. Although the nature of possible contributing waste streams has been surveyed, and documented, information on the flow of each individual waste stream at various operation times is not available. It is suggested that these flow rates be investigated.

4. On-site analyses of combined wastewater characterization would, indeed, provide information to determine the chemical dosages for wastewater treatment. It is feasible only if portable field test kits for rapid determination of certain critical parameters can be developed. Another alternative is providing on-site measurement of the flows of every contributing waste stream to the combined wastewater equalization tank. Knowing the measured flow data and the surveyed nature data for each contributing waste stream, the operator can then calculate the nature of combined wastewater to be treated. The feasibility of on-site measurement of wastewater flows is subjected to further field investigations.

5. Synthetic wastewater prepared with tap water, laundry detergent, dishwasher detergent, ground bar soap, Bentonite clay, lubricating oil and canned dog food was found to have characteristics similar to those of the combined wastewater derived from field kitchens, laundries, and showers.

6. The laboratory-prepared synthetic wastewater is approximately equivalent to a domestic sewage of medium strength, according to Babbitt and Baumann's (Ref. 27) sewage classification.

7. The characteristics of tap water, detergents, soap, clay, oil, and dog food, which were used for synthetic wastewater preparation, were also quantitatively determined and discussed. With this information available, any other synthetic wastewaters can also be prepared by varying the proportions of the materials added. In the event that photographic wastewater, washrack wastewaters and hospital wastewaters are to be considered for combined waste treatment, additional substances such as heavy metals and refractory organics should also be added to the synthetic wastewater formulation.

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APPENDIX I

WATER REQUIREMENTS FOR ARMY FIELD OPERATIONS

(Source: U.S. Army Mobility Equipment Research & Development Center)

1	1 Unit consumer	2 Conditions of use	3 Gallons per unit consumer per day Temperate cold climate	4 Gallons per unit consumer per day Desert/jungle	5 Remarks
2	Man	In combat:			
		Minimum	½–1	2–3	For eating and drinking only; periods not to exceed 3 days.
			2	3–4	When field rations are used.
		Normal	3	6	Drinking plus small amount for cooking or personal hygiene.
		March or bivouac	2	5	Minimum for all purposes.
		Temporary camp	5	--------	Desirable for all purposes (does not include bathing).
		Temporary camp with bathing facilities	15	--------	Includes allowance for waterborne sewerage system.
		Semipermanent camp	30–60	--------	--------
		Permanent camp	60–100	--------	--------
3	Vehicle	Level and rolling country	⅛–½	--------	Depending on size of vehicle.
		Mountainous country	¼–1	--------	Depending on size of vehicle.
4	Locomotive	Standard military	Variable	--------	95 gallons per train-kilometer.
		Commercial	Variable	--------	125 gallons per train-kilometer.
5	Hospital	Standard 2	50 per bed	--------	Includes water for medical personnel; sewage not waterborne.
		Standards 3, 4, 6	85 per bed	--------	Includes water for medical personnel and for waterborne sewage.
6	Impregnating plant, clothing	Maximum impregnating capacity	2,400	--------	Aqueous process. Includes 2,000 gallons for washing and cleaning purposes.
7	Bakery section	Two 10-hour shifts	1,400	--------	Water for making bread and cleaning baking utensils.
8	Laundry unit	Two 10-hour shifts	4,000	--------	--------
9	Shower unit	--------	9,800	--------	--------
10	Decontaminating apparatus, 400-gallon, truck-mounted	Decontamination	4,000	--------	Water obtained from natural source when available.
11	Chemical base laboratory, M2	Normal laboratory work	300	--------	--------

APPENDIX II

WATER EQUIPMENT ISSUED TO U.S. ARMY ENGINEERING UNITS

(Source: U.S. Army Mobility Equipment Research & Development Center)

	1	2	3	4	5	6	7	8	9	10	11	12
1	Unit	TOE	Number of sets [1]	Type of purification unit (fresh water) (gph)	Generator (kw)	Equipment in each set: Tank: Number	Equipment in each set: Tank: Capacity (gal)	Pump discharge (gpm per set) [2]: Distribution	Pump discharge (gpm per set) [2]: Purification	Total storage capacity (gal)	Maximum production (gph)	Water transport equip
2	Engr bn, abn div	5-25G	5	600	3	2	1,000	65	10	5,000	3,000	
3	Engr cbt bn, army or corps	5-35G	5	1,600	10	2	6,000	125	25	30,000	7,500	
4	Engr WS co	5-67G	9	3,000 (mbl)	10	2	6,000	125	50	54,000	27,000	12 1,000-gal tk trk.
5	Engr co, sep inf bde	5-107G	2	1,500	10	2	6,000	125	25	12,000	3,000	HEA 2000 gal semi TRLR.
6	Engr CB	5-115G	2	1,500	10	2	6,000	125	25	12,000	3,000	
7	Engr co, sep armd or inf (mech) bde	5-127G	2	1,500	10	2	6,000	125	25	12,000	3,000	
8	Engr co, sep abn bde	5-137G	1	600	3	2	1,000	65	10	1,000	600	
9	Engr bn, armd and inf (mech) div	5-145G	5	1,500	10	2	6,000	125	25	30,000	7,500	
10	Engr bn, inf div	5-155G	5	1,500	10	2	6,000	125	25	30,000	7,500	
11	Engr cbt bn, abn	5-195G	3	600 (mbl)							1,800	
12	Engr co, sep lt inf bde	5-207G	2	1,500 (mbl)							3,000	
13	Engr bn, airmbl div	5-215T	5	600 (mb)							2,500	
14	Well-drilling tm, abn (GF)	5-520G	1	Well-drilling set.								
15	Water purification tm (CG)	5-520G	1	3,000 (base)	10	3	3,000	125	50	9,000	3,000	
16	Water purification tm (GH)	5-520G	4	3,000 (base)	10	12	3,000	125	50	3,000	12,000	
17	Water trans tm (GJ)	5-520G										5 1,000-gal tk trk.
18	Water distillation tm (GI)	5-520G	1	6,000							6,000	

[1] Each set can equip one water point.

[2] One pump at steady purification rate; others at full-rated capacity for distribution (intermittent operation).

APPENDIX III

U.S. ARMY ADOPTED ITEMS OF MATERIEL FOR FIELD OPERATIONS

LIN / FSN OR ACVC	SC	CIC	RICC	GENERIC NOMENCLATURE / FSN OR ACVC NOMENCLATURE	UNIT PRICE	U/I	PAC	CMC	RIC / ILP	TYPE CLASS	TYPES OF REQUIREMENTS / REFERENCE DATA
Y30972	20	0	0	WASHING MACHINE LAUNDRY COMMERCIAL: 25 LB DRY WT CAP		EA	2	E	A35		TDA
3510-288-6223				WASH MACH COMM 50 CY	1,044.00				0	A	
3510-283-6350				WASH MACH COMM 60 CY	1,287.00				0	A	
*3510-266-9396				WASH MACH COMM 25 LB	1,000.00				0	B 5907 68	
Y31109	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 50 LB DRY WT CAP		EA	2	E	A35		TDA
3510-174-3181				WASH MACH LDRY 50 LB	5,539.00				0	A Q5 56	
Y31246	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 110 LB DRY WT CAP		EA	2	E	A35		TDA
3510-240-1821				WASH MACH LDRY 110 LB	5,500.00				0	A Q5 56	
Y31383	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 225 LB DRY WT CAP		EA	2	E	A35		TDA
3510-141-8613				WASH MACH 225LB E CON	6,000.00				0	B QM 4-60	
3510-141-8629				WASH MACH 225LB B CON	6,000.00				0	B 5907 68	
Y31520	20	0	0	WASHING MACHINE LAUNDRY COMMERCIAL: 350 LB DRY WT CAP B CON		EA	2	E	A35		TDA
*3510-882-0666				WASH MACH COM 350 50C	6,192.00				0	A	
*3510-[illegible]4-4728				WASH MACH COM 350 LB	6,192.00				0	B 5907 68	
Y31657	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 350 LB DRY WT CAP E CON		EA	2	E	A35		TDA
3510-643-4547				WASH MACH 350LB 50C E	6,153.00				0	A	OO-W-50 TIV
3510-141-8627				WASH MACH 350LB 60C B	4,929.00				0	A QM 4-60	OO-W-50 TIV
3510-141-8633				WASH MACH 350LB 60C E	6,971.00				0	A QM 4-60	OO-W-50 TIV
Y31794	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 400 LB DRY WT CAP E CON		EA	2	E	A35		TDA
3510-141-8635				WASH MACH LDRY 400 LB	6,552.00				0	A Q5 56	
Y31931	20	0	3	WASHING MACHINE LAUNDRY COMMERCIAL: 1200 LB DRY WT CAP		EA	2	E	A35		TDA
3510-781-1143				WASH MACH 1200LB 50CY	19,246.00				0	A	
3510-878-9805				WASH MACH 1200LB 60CY	20,412.00				0	A	
* Y32431	8X	0	0	WASTE RECEPTACLE STEP-ON TYPE: CORROSION-RESISTING-STEEL 3 GAL		EA	2	C	B69		TOE TDA
7240-788-3953				WASTE RECEP CRS 3 GAL	25.70				0	A MED10 62	C6700/9600-IL
Y32568	2E	0	0	WASTE RECEPTACLE SWINGING DOOR: 18L 18W 34H IN		EA	2	E	A35		XSB
7240-285-8216				WASTE RECEPTACLE SW D	.99				0	B QM 2-60	
* Y34527	8X	0	0	WATER BATH ELECTRIC: SEROLOGICAL 6 RACK 110-220 VOLT AC		EA	2	C	B69		TDA
6640-403-0460				WATER BATH ELEC 110-2	147.00				0	B 40 3-68	DOD-C-6600-IL
* Y34664	8X	0	0	WATER BATH ELECTRIC: SEROLOGICAL 110 VOLT 60 CYCLE AC		EA	2	C	B69		TDA
*6640-403-0420				WATER BATH ELEC SEROL	96.00				0	B M6 1-70	DOD-C-6600-IL
* Y34938	8X	0	0	WATER BATH SEROLOGICAL: 10 RACK 100-220 VOLT 60 CYCLE AC		EA	2	C	B69		TDA
6640-403-0485				WATER BATH ELEC 10 RA	224.00				0	B 40 3-68	DOD-C-6600-IL
Y35075	7G	0	2	WATER CONDITIONER PHOTOGRAPHIC: PH-644/UF		EA	1	G	B16		
6740-356-5397				WATER CONDTR PH-644UF	2,036.09				X	A 0704	

APPENDIX III (Cont.)

U.S. ARMY ADOPTED ITEMS OF MATERIEL FOR FIELD OPERATIONS

LIN FSN OR ACVC	SC	CIC	RICC	GENERIC NOMENCLATURE FSN OR ACVC NOMENCLATURE	UNIT PRICE	U/I	PAC	CMC	RIC ILP	TYPE CLASS	TYPES OF REQUIREMENTS REFERENCE DATA
Y36592 4610-649-8385	7B	C	2	WATER PURIF UNIT VAN BODY: ELEC DRVN AC DC 115-208V 1-3 PH 60 CY WTR PURIF TM 3M-2700	12,296.00	EA	1	B	A12 0	N PENDING	TDA
Y36719 4610-649-8386	7B	C	2	WATER PURIF UNIT VAN TYPE BODY: 1500 GPH WTR PURIF VAN 15-2600	11,259.00	EA	1	B	A12 0	N PENDING	TDA
Y36856 6630-262-7288	20	0	3	WATER QUALITY CONTROL SET: RECON AND ROUTINE WTR QUAL CONTROL ST	197.00	SE	1	B	A12 X	B 3021 65	TOE TDA SC 6630-CL-E01
Y36993 6640-498-9523	7G	0	3	WATER STILL: MX-775/U WATER STILL MX-775/U	200.00	EA	2	G	B16 0	A SIG 1744	TDA
• Y37130 6665-682-4765	8X	0	0	WATER TESTING KIT BACTERIOLOGICAL: WATER TES KIT BACTERI	423.00	EA	2	C	B69 0	A MED 8650	TOE DOD-C-6600-IL
Y37267 6665-171-9747	2E	0	0	WATER TESTING KIT CHEMICAL AGENTS: WATER TEST KT CML M2	9.65	EA	2	N	B54 X	A C3450 58	XSB
Y37404 6665-542-1239	2E	C	7	WATER TESTING KIT POISONS: WATER TEST KT M4A1	401.45	EA	2	N	B54 X	A C3629 59	TOE TDA OP
Y37904 3805-377-0600	9B	0	0	WATERPROOF KIT: FOR TRACTOR FULL TRACK AND GRADER MTRZD WATERPROOF KIT F/TR F	49.66	EA	2	B	A12 0	A E610 58	OP
Y35143 *4610-937-0223	7B	C	2	WATER PURIF EQUIP SET: DIATOMITE FILTER 420 GPH WTR PURIF 420 GPH	6,000.00	SE	1	B	A12 0	U 6818 69	TOE
Y35212 *4610-540-4024	7B	C	1	WATER PURIF EQUIP: TRLR MTD DIATOMITE FILTER 600 GPH WTR PURIF EQUIP TRLR	14,413.00	SE	1	B	A12 X	A E1897 58	TOE TDA OP SC 4610-CL-E03
Y35486 4610-[illegible]	7B	C	1	WATER PURIF EQUIP SET: TRK MTD DIATOMITE FILTER 1500 GPH (ARMY) WTR PURIF TM 1500 GPH	31,529.00	SE	1	B	A12 X	A E2786 58	TOE TDA OP SC 4610-CL-E05
Y35760 4610-202-8700	7B	C	2	WATER PURIF EQUIP SET: BASE MTD DIATOMITE FILTER 3000 GPH (ARMY) WTR PURIF BM 3M GPH	20,123.00	SE	1	B	A12 X	A E1396 58	TDA OP SC 4610-CL-E07
Y36034 4610-202-8701	7B	C	1	WATER PURIF EQUIP SET: TRK MTD DIATOMITE FILTER 3000 GPH (ARMY) WTR PURIF TM 3M GPH	39,667.00	SE	1	B	A12 X	A E2787 58	TOE TDA OP SC 4610-CL-E06
Y36239 4610-902-3106	7B	C	1	WATER PURIF SET: PRBL 600 GPH WTR PURIF ST 600 GPH	4,902.00	SE	1	B	A12 0	B 6638 69	TOE
Y36308 4610-857-0380	7B	C	2	WATER PURIF UNIT BASE MTD: 3000 GPH ELEC AC110 208V 1-3 PH 60 CY WTR PURIF 3000-2700A	[illegible]	EA	1	B	A12 0	A 2166 64	TOE TDA
Y36445 4610-649-8387 4610-678-8810 4610-726-1237	7B	C	2	WATER PURIF UNIT TRLR MTD: 600 GPH ELEC AC DC 115 V 1 PH 60 CY WTR PURIF TM 600-2500 WTR PURIF TM MDL 600 MET-PRO 600A	 7,014.00 7,014.00 7,014.00	EA	1	B	A12 0 0 0	 N PENDING N PENDING N PENDING	

APPENDIX IV

CHARACTERISTICS OF TAP WATER DURING THE PERIOD OF FIELD WASTEWATER CHARACTERIZATION STUDIES*

(SOURCE: U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT CENTER)

PARAMETER (mg/ℓ EXCEPT AS NOTED	CHEMICAL ANALYSIS			SUMMARY		
	A. (2 AUGUST 1972)	B. (3 AUGUST 1972)	C. (4 AUGUST 1972)	MIN.	AVE.	MAX.
TURBIDITY, JTU	0.34	0.58	0.46	0.34	0.46	0.58
pH, UNIT	7.9	7.7	7.5	7.5	7.7	7.9
TOTAL DISSOLVED SOLIDS	135.0	140.0	145.0	135.0	140.0	145.0
DETERGENT	0.04	0.04	0.02	0.02	0.03	0.04
TOTAL PHOSPHATE	20.0	5.0	2.0	2.0	9.0	20.0
ORTHO PHOSPHATE	12.0	5.0	2.0	2.0	6.3	12.0
POLY PHOSPHATE	8.0	0.0	0.0	0.0	2.7	8.0
SULPHATE	22.0	12.0	35.0	12.0	23.0	35.0
SILICATE	36.0	37.0	35.0	35.0	36.0	37.0
TOTAL HARDNESS ($CaCO_3$)	12.0	20.0	14.0	12.0	15.3	20.0
CALCIUM HARDNESS ($CaCO_3$)	12.0	16.0	12.0	12.0	13.3	16.0
MAGNESIUM HARDNESS ($CaCO_3$)	0.0	4.0	2.0	0.0	2.0	4.0
TOTAL ALKALINITY ($CaCO_3$)	108.0	194.0	118.0	108.0	140.0	194.0
CHLORIDE	10.0	––	––	––	10.0	––

*CONTROL DATA FOR THE FIELD WASETWATERS INDICATED IN TABLES 3, 5, 7, AND 11.

APPENDIX V

PHYSICAL CHARACTERISTICS OF DOMESTIC SEWAGE

Characteristic	Cause	Significance	Measurement
Temperature	Ambient air temperature. Hot water discharged into sewer from home or industry.	Influences rate of biological activity. Governs solubility of oxygen and other gases. Affects magnitude of density, viscosity, surface tension, etc.	Standard centigrade or Fahrenheit scale.
Turbidity	Suspended matter such as sewage solids, silt, clay, finely divided organic matter of vegetable origin, algae, microscopic organisms.	Excludes light, thus reducing growth of oxygen-producing plants. Impairs aesthetic acceptability of water. May be detrimental to aquatic life.	Light scatter and absorption on an arbitrary standard scale.
Color	Dissolved matter such as organic extractives from leaves and other vegetation (tannins, glucosides, iron, etc.), industrial wastes.	Harmless generally, but impairs aesthetic quality of water.	Light absorption on a standard arbitrary scale.
Odor	Volatile substances, dissolved gases, often produced by decomposition of organic matter. In water it may result from the essential oils in microorganisms.	May indicate presence of decomposing sewage. Affects aesthetic quality of water. As a test of sewage it may serve, for example, as a guide to condition of sewage when it reaches the treatment plant.	Human sense of smell, qualitative scale, and concentration at threshold of odor.
Taste	Materials producing odors. Dissolved matter and various ions.	Impairs aesthetic quality of water.	Not measured in unpotable water.
Solid matter	Dissolved and suspended organic and inorganic solids.	Measures amount of organic solids, silts, etc., hence is a measure of the extent of sewage pollution or the concentration of a sewage.	By gravimetric analysis techniques for the following: Total solids, total volatile solids, total fixed solids, suspended solids, and dissolved solids.*

APPENDIX VI

COMPOSITION OF DOMESTIC SEWAGE

[All values in milligrams per liter]

Constituent	Strong	Medium	Weak
Solids, total	1000	500	200
Volatile	700	350	120
Fixed	300	150	80
Suspended, total	500	300	100
Volatile	400	250	70
Fixed	100	50	30
Dissolved, total	500	200	100
Volatile	300	100	50
Fixed	200	100	50
BOD (5-day, 20°C)	300	200	100
Oxygen consumed	150	75	30
Dissolved oxygen	0	0	0
Nitrogen, total	86	50	25
Organic	35	20	10
Free ammonia	50	30	15
Nitrites (NO_2)	0.10	0.05	0
Nitrates (NO_3)	0.40	0.20	0.10
Chlorides	175	100	15
Alkalinity	200	100	50
Fats	40	20	0

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